Pest Management Grants Final Report

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Project Title: Evaluation of cultivars for yield in organic strawberry production in the presence or absence of mycorrhizal inoculum

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Many assistants from each institution have worked on various aspects of this project. Here we acknowledge the five most significant contributors; Adria Bordas, Joel Stryker, Rose Vega, E. J. Rowland, and Jim Leap. Many CASFS interns and student workers provided large amounts of labor needed to take the data in the plots.

We are indebted to the help we received from the growers who were directly involved with the research. In particular we thank Christine Coke, Paul Kohatsu, Phil Foster and Stuart Yamamoto for volunteering their land and/or labor. Jim Leap needs to be acknowledged as a key grower who served as an excellent liason between the growers and scientists, because he has one foot in each world.

Reggie Knox and the CAFF team provided a backbone to the projected. The CAFF team helped us to effectively get the information we were generating out to the growers. It is large part because of their well-oiled outreach machine that we were able to have on-going grower feedback throughout this project.

Lastly we acknowledge the ideas and input we received from all the growers we have interacted with over the past three years of this project. The have assured us of the importance of the long hours we were working.

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Abstract

Two and three field trials were conducted during the 2000-2001 and 1999-2000 growing seasons, respectively, to compare the performance of a total of 13 strawberry cultivars in organic production fields. The cultivars evaluated were Aromas, Carlsbad, Chandler, Diamante, Douglas, Irvine, Hecker, Oso Grande, Pacific, Pajaro, Seascape, Sequoia, and Selva. Aromas was the top performing cultivar in three of the five experiments conducted while Seascape was the top performer in the other two experiments. Aromas, Seascape, and Pacific where the top three performing cultivars across all five experiments. Six additional experiments were conducted to evaluate the effect of commercially available mycorrhizal products on strawberry performance in organic and conventionally managed production fields. Mycorrhizal colonization of the transplants used in the second season was higher than the levels for transplants from the first season. After planting neither cultivar, nor inoculation with commercially available inoculants, influenced the levels of colonization detected. The time of sampling was the only factor that had a significant influence on colonization. In most experiments, colonization reached its highest level in March. Yield from plants that received no treatment (controls) did not differ significantly from the yield of plants inoculated with commercially available inoculants in either organic or conventional research plots.

Executive summary

The three main objectives of this project were as follows:
Objective 1. Evaluation of cultivar performance under organic conditions.
Objective 2. Evaluation of Mycorrhizal inoculants.
Objective 3. Evaluation of disease in research plots.

Through a collaborative effort between the USDA/ARS, UCCE, and CASFS at UC-Santa Cruz and five organic strawberry growers the objectives of this grant were met within the time frame set out in the agreement. The USDA/ARS was responsible for establishing and evaluating performance and disease at five of the research locations with the help of the UCCE. CASFS established and evaluated the plots located on their land. Local organic growers were responsible for growing the crops in accordance with organic production regulations. Additionally, a large group of growers participated in the selection of the cultivars to be tested. For this reason the cultivars changed from the first year to the second.

A total of 13 cultivars were evaluated (ten in each experiment) in the first side-by-side comparisons conducted in certified organic production fields. At three locations, yield was statistically analyzed from replicated small plot trials. A total of five replicated trials were conducted. At the fourth location a large-scale grower demonstration was conducted but the data was not analyzed statistically due to the large plot size leading to a lack of replication. In the replicated and analyzed trials, three cultivars topped the list most often. Aromas, Seascape, and Pacific were the top performing cultivars in these experiments. In some cases these cultivars had yields that were statistically different from yields of cultivars that are currently used by large numbers of California growers (for example cv. Diamante). This is the first data available to organic growers to help them with cultivar selection based on trials in organic production systems.

The collaborative group also evaluated commercially available mycorrhizal inoculants for the ability to increase performance of organically and conventionally managed strawberries. The commercial inoculants did not influence yield, disease levels or even colonization of roots by mycorrhizae in the six field trials conducted.

Major diseases were absent from most of the field trials with one significant exception. During the second year at one location, *Verticillium dahliae* decimated the plot. It appeared that an interaction between the pathogen and the presence of symphylans, *Scutigerella immaculate* increased the problem. This arthropod is becoming an increasingly important soilborne pest in the central coast region and control measures may become more important in the absence of methyl bromide fumigation.

To-date this research has been discussed at 10 grower meetings and in 12 popular press articles or broadcasts. Results have been published as proceedings and/or presented at eight scientific meetings. Importantly, the data will be included in an Organic Strawberry Production Manual that is currently under development.

Introduction

Strawberry is one of the most important crops in California. This may be because California has the most productive strawberry fields in the world due to 50 years of research optimizing cultivars and cropping practices in the context of soil fumigation with methyl bromide and chloropicrin (MBC). Preplant fumigation with a mixture of MBC is an important tool in obtaining high strawberry yields in conventional production fields due to its ability to control soilborne pests and weeds. In fruiting fields, fumigation insures a return on the investment required for crop production (~25,000). However, methyl bromide is a class I ozone depleter, and as such is scheduled for a 50% and 100% use reduction in 2001 and 2005, respectively.

In spite of the dominance of commercial production and the high risk involved in strawberry production in the absence of MBC, the number of growers producing certified organic strawberries is steadily increasing. The number of strawberry growers certified by one leading certification organization in California has increased by 27 % from 1999 *to 2001 (CCOF 1999, 2001). Experiments comparing organic and conventional* production have reported yields for the organic plots as high as 72% of conventional yields (Gliessman et al., 1996). That growers are able to attain these yields often on marginal land, with virtually no research support suggests that research conducted in an organic context should help to optimize their production systems. Although organic production is the state-of-the-art production method in the absence of MBC fumigation, there is little research aimed at optimizing this alternative to the soon-to-be banned fumigant.

Although choice of variety is very important for success, the performance of commercially available cultivars had never been compared in organic fields. High yielding cultivars were evaluated and selected for their yield and fruit quality in conventional production practices (Larson and Shaw, 1995). Organic growers rely on cultivars designed for use in MBC fumigated soils although cultivars perform differently in fumigated and non-fumigated conventional fields (Martin 2001b). Organic fields are even less similar to the fields in which the cultivars were selected.

A comparison of strawberry cultivars was conducted in organic production fields. In the research reported here five experiments compared 13 cultivars at three locations during two field seasons in the central coast region of California. This is the first reported side-by-side comparison of commercially available varieties on certified organic land.

Microbial inoculants are tools that can be used by organic growers to mitigate plant disease or promote plant growth. Because organic production systems are microbially diverse it is unknown if microbial inoculants can improve strawberry performance in these production systems. In six experiments, seven commercially available inoculants containing vesicular arbuscular mycorrhizae, were evaluated for their ability to enhance performance and root colonization.

Methods and Results

This research evaluated the performance of mycorrhizal inoculants and commercially available cultivars in organic strawberry production. At five different production locations (Table 1) replicated evaluations were made using small plots during the two years of these studies. At a sixth location cultivar evaluation were conducted on large scale as a grower demonstration during the 1999-2000 growing season. Organic strawberry production and management were consistent with practices outlined by California Certified Organic Farmers (Health and Safety Code number 26569.11) but were determined by the individual farm managers.

Performance of cultivars

The performance of ten cultivars was evaluated at two locations during the 2000-2001 and four locations during the 1999-2000 growing seasons. At one location during the 1999-2000 growing season the trial was not replicated but was a large-scale demonstration for growers and therefore data is not presented for that location. At each location ten newer and older cultivars were evaluated. The cultivar choices were made at grower meetings held in 1999 and 2000.

Transplants were evaluated for colonization by mycorrhizae prior to planting. During the fall of 1999 and 2000, cultivars were planted on three different dates according to the optimum planting dates suggested by the nurseries.

For these experiments, each plot consisted of 60 plants of one cultivar. Treatments were applied to split plots. One half of the plot was planted with 30 strawberry transplants that had been inoculated with mycorrhizae (Endomycorrhizal Inoculum, BioOrganics) prior to planting. The other half of the plot did not receive any microbial treatment. There were four replications of each cultivar at each location.

Yield was evaluated on 20 plants from each plot. Mature fruit were harvested once (locations A and B) or twice (locations D and E) weekly. Market quality fruit were weighed separately from culls. Analysis of variance was used to determine if differences existed in the market yield of the cultivars evaluated.

Prior to planting, the level of *Verticillium dahliae* in the soil at each research site was evaluated using standard techniques (Xiao et al., 1997). Additionally weak plants were evaluated for infection by *V. dahliae* during the season. At location B, the residue from a broccoli crop was incorporated to reduce the level of the pathogen in the soil prior to each planting season. In this case the presence of the pathogen was assessed prior to incorporation and directly before strawberry planting.

At location B, beet traps were used to sample for the presence of symphylans, *Scutigerella immaculata*. This location has had problems with symphylans in the past. This arthropod pest is becoming an increasingly important soilborne pest in the central coast region.

On a monthly basis visual ratings for biotic and abiotic diseases were conducted. The disease incidence was recorded for each plot in order to determine if there were any differences among cultivars or plants treated with different inoculants. No major problems with abiotic diseases were found. Similarly, few biotic plant diseases were detected on foliage and fruit (data not shown).

The levels of *V. dahliae* in soils were low at most locations. For example for the 2000-2001 season locations B, C, D, and E had 0.2, 0.3, 0.8, and 0.2 micorsclerotia per gm soil, respectively. Although location B had a relatively low level of microsclerotia in the soil, the plot was decimated in late June. The plants appeared to have Verticillium wilt. This was confirmed by isolating the pathogen from infected tissue. At location B, the levels of infestation by symphylans were high in the border regions of the plot at the beginning of the season. The distribution of stunted and killed plants later in the season suggested that an interaction may be occurring between *V. dahliae* and symphylans, but this could not be tested due to the limited testing for symphylans. The role of symphylans in the severity and spread of Verticillium wilt needs to be assessed.

During the 1999-2000 season, Location B had the highest market yields among the locations at which the experiments were conducted (Figures 1 and 2). This is because this ranch markets its fruit directly to consumers and berries that would be culls because of transportation problems can be marketed. In the 2000-2001 season, this ranch had a lower yield due to problems with *V. dahliae* and symphylans.

In all five trials there was no significant effect of mycorrhizal inoculation on the yield or colonization by mycorrhizae for the cultivars tested in organic production systems. Data from inoculated and uninoculated plots were therefore analyzed together. Aromas, Pacific, Seascape and Selva were always in the top six performing cultivars (Figures 1 and 2, Table 2). Aromas was the highest performing cultivar in three of the five experiments. Seascape was the highest performing cultivar in the two experiments in which Aromas was not the greatest yielding cultivar. Organic growers involved in these experiments preferred Seascape to Aromas for taste and shipping quality. Currently, Diamante is most planted strawberry cultivar in California, but it performed relatively weakly compared to the other cultivars tested in certified organic fields. Overall, Aromas, Pacific and Seascape performed the best in these trials (Table 2; Bull et al., 2001).

Role of mycorrhizal colonization on yield

For all experiments mycorrhizal colonization was monitored on transplants prior to planting and throughout the growing season. Ten plants of each cultivar were tested using standard methods for evaluating mycorrhizal colonization (Kormanik and McGraw, 1982). Roots were sampled destructively during the experiments to estimate colonization. Colonization was estimated at three times during the growing season. For statistical analysis, percent colonization data were arcsin transformed prior to analysis of variance using a split plot model; however, data are presented as percent colonization.

In addition to comparing the effect of one inoculant on 10 cultivars as was described in the previous section, we compared the ability of seven mycorrhizal inoculants (Table 3) to enhance the performance of a single cultivar in three independent experiments. Four of the trials were conducted on organically managed farms as described previously and two trials were conducted on a conventional plot that had not been fumigated for two years. Each plot consisted of 30 plants (cv. Aromas or Diamante) and there were four replications per treatment. Plots with uninoculated plants were negative controls. The mycorrhizal inoculants were applied as a root application or were applied to the soil as per manufacturer's recommendations. The mycorrhizal status of the transplants was evaluated prior to treatment and at two or three times during the growing season.

Transplants used in the 2000-2001 season were colonized to a greater extent (over 20 % greater in most cases) than the transplants used in the 1999-2000 season (Table 4). In the 1999-2000 season 0 to 1.7 % of the roots of transplants were colonized and no significant differences were detected (P=0.05) among cultivars. Colonization of transplants ranged from 11.7 to 37.1 % for the 2000-2001 season and there were differences in colonization among cultivars. There were also differences in the level of colonization of Diamante transplants grown at different nurseries (Table 4).

The time of sampling was the only factor that had a significant influence on colonization (Table 5). The lowest level of colonization was detected on the transplants prior to planting. The level of colonization was greater in January than on transplants but lower than on plants evaluated later in the season. In two of the experiments there was no difference in colonization in March and May but in one experiment the level of colonization was lower in May. Lower colonization later in the season may represent root growth without a proportional increase in colonization. These results are similar to our findings from the previous year and in experiments described in the first objective.

There was no interaction between treatment and sampling times in any of the experiments, so only the main effects are presented (Tables 5 and 6). In all experiments, inoculation did not influence colonization. There was no statistical difference detected at the P=0.05 level for colonization between uninoculated plants and any of the commercially available inoculants (Table 6). This result suggests that indigenous inoculum either in the soil or on the transplants is as effective at colonizing strawberry roots as the inoculants.

None of the mycorrhizal inoculants tested had an influence on the yield of strawberries in organic or conventional production fields (Table 7). At location B during the 1999-2000 growing season the yield of plants inoculated with two different inoculants were significantly different (P=0.03) according to Tukey-Kramer HSD. Otherwise no significant differences among treatments were detected. Yields of uninoculated plants were not different than the yields of plants inoculated with any of the commercial inoculants. These data indicate that the commercially available inoculants tested do no influence yield in certified organic production fields.

Discussion and Conclusions

Increased yield in organic production could make this production method a more viable alternative to MBC fumigation and other chemicals used by strawberry farmers. Since synthetic pesticides, fumigants or fertilizers are not used in organic production, acreage converted to organic production will reduce the amount of these chemicals used. This will in turn reduce risk of exposure to the chemicals used on strawberry farms for the workers, environment, consumers, and general public.

Organic strawberry farmers rely on information extrapolated from research conducted on conventional production land. Chief among the information that they rely on is information about cultivar choice. It has become clear over the past few years in research conducted by the USDA/ARS that high yielding cultivars used in California perform differently in fumigated and non-fumigated soils (Martin, 2001b). Here we show that the cultivars Aromas, Seascape, and Pacific are the highest yielding varieties in organic production fields. This is interesting because Aromas, Seascape, and Pacific have been shown to be tolerant at least one of the following soilborne pathogens *Pythium ultimum*, *Phytophthora cactorum* and *Verticillium dahliae* (Martin, 2001a; Browne et al., 2001; Dunniway et al., 2001). This indicates that cultivars bred for resistance to these pathogens may perform well in organic production systems for which soil sterilization through fumigation is not an acceptable practice. Diamante, which is currently the cultivar of choice for many conventional growers, did not perform as well as other cultivars under organic management. Some private companies are now making cultivar selections in non-fumigated or organically managed fields in order to select cultivars that will perform better under these conditions. The proprietary varieties will not be available to growers without direct agreements with these companies.

This research did not set out to compare the performance of strawberry cultivars in organic verses a conventional system. Instead the goal of this research was to provide organic growers with side-by side comparisons of commercially available cultivars in certified organic production fields. These small-scale trials should be only a guide for organic growers, because differences in resistances to insect pests may occur when large areas are planted to a single cultivar.

There are approximately 12 microorganisms that are currently registered as the active ingredients as biopesticides by the US-EPA. Of these pesticides very few have been made available to organic growers. Mycorrhizal inoculants are not registered as pesticides but are considered inoculants to stimulate growth and a number of these are registered by OMRI. Organic growers have been interested in mycorrhizal interactions for many years as is evidenced by the number of talks presented at organic grower meetings. Though many microbial inoculants can be used in organic management and they have been shown to mitigate plant disease and promote plant growth in conventional cropping systems, little is known about the effect of microbial inoculants or natural microbial colonist on plant health in organic systems. Organic strawberry production does not rely on fumigation, which can virtually sterilize the soil. Thus it was previously unknown if inoculation with mycorrhizae was needed to establish early or adequate colonization. The lack of effect of any of the tested inoculants on colonization and yield, suggest that indigenous inoculum either in the soil or on the transplants is as effective at colonizing strawberry roots as the inoculants.

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Tables and Figures

Table 1. Locations used for research experiments.

Designation	Location	Farm	Grower
A	San Juan Bautista	Coke Farm	Christine Coke
B	Santa Cruz	UCSC organic farm	Jim Leap
C	Watsonville	Monterey Bay Academy	Stuart Yamamoto (Coastal Berry)
D	Salinas	Spence Organic Field	Paul Kohatsu
E	Salinas	Spence Conventional Field	Paul Kohatsu
F	San Juan Bautista	Phil Foster Ranch	Phil Foster

Table 2. Overall performance of commercially available cultivars grown in certified organic production fields.

	Performance ranking					Overall
	1999-2000			2000-2001		Ranking/number of experiments
	A	B	D	B	D	
Aromas	3	1	1	6	1	2.4
Pacific	2	2	3	4	3	2.8
Seascape	1	3	5	1	6	3.2
Selva	4	5	4	5	2	4
Carlsbad		8	6	3	4	5.3
Diamante	6	6	2	9	5	5.6
Douglas	5	7	8	2	8	6
Irvine	7					7
Chandler				7	7	7
Hecker	10	4	10			8
Oso Grande				8	9	8.5
Sequoia	8	9	9			8.7
Pajaro	9	10	7	10	10	9.2

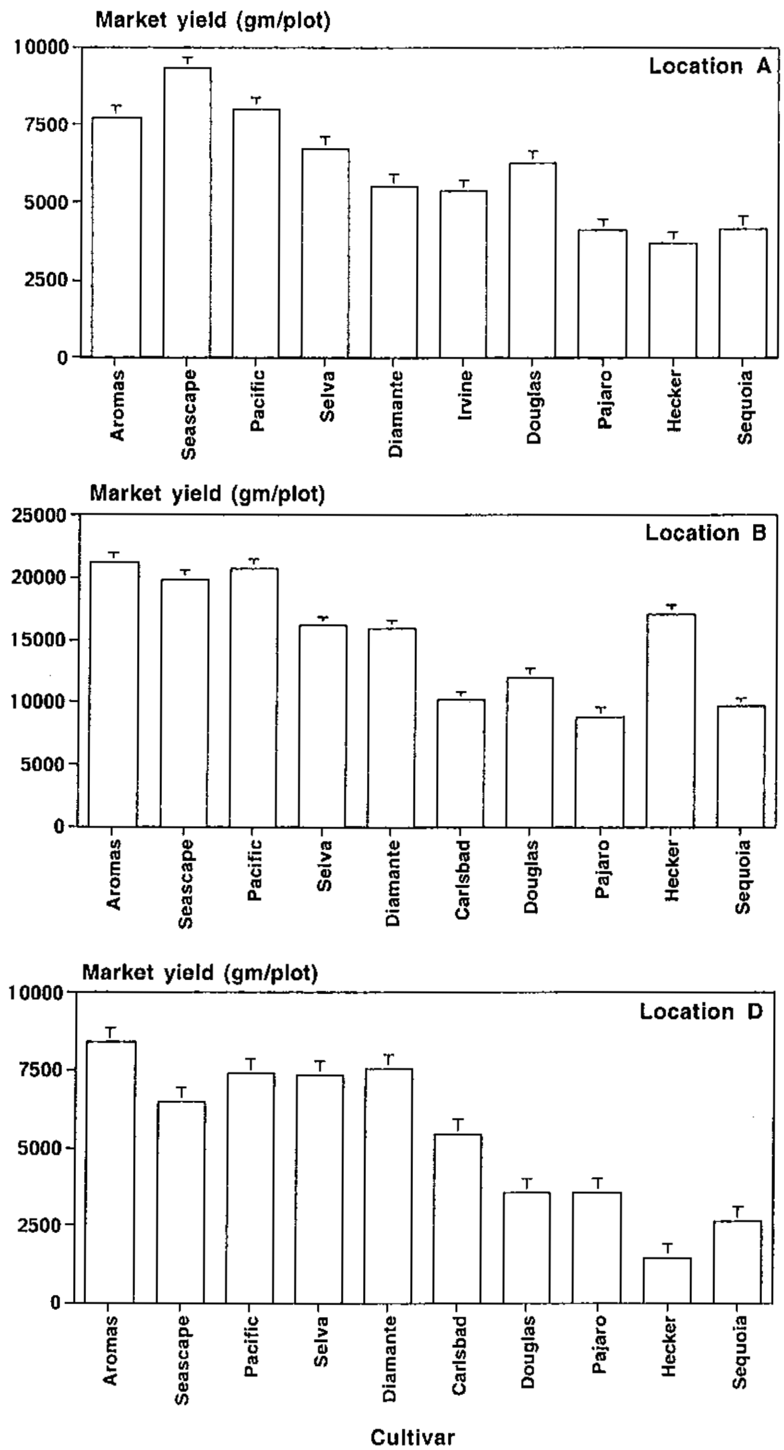

Figure 1. Cumulative market yield of commercially available cultivars grown under organic management in certified organic fields (1999-2000). Yield was measured on 20 plants per plot by weighing marketable fruit once (Locations A and B) or twice (Location D) weekly. Perpendicular bars represent the standard error for the experiments.

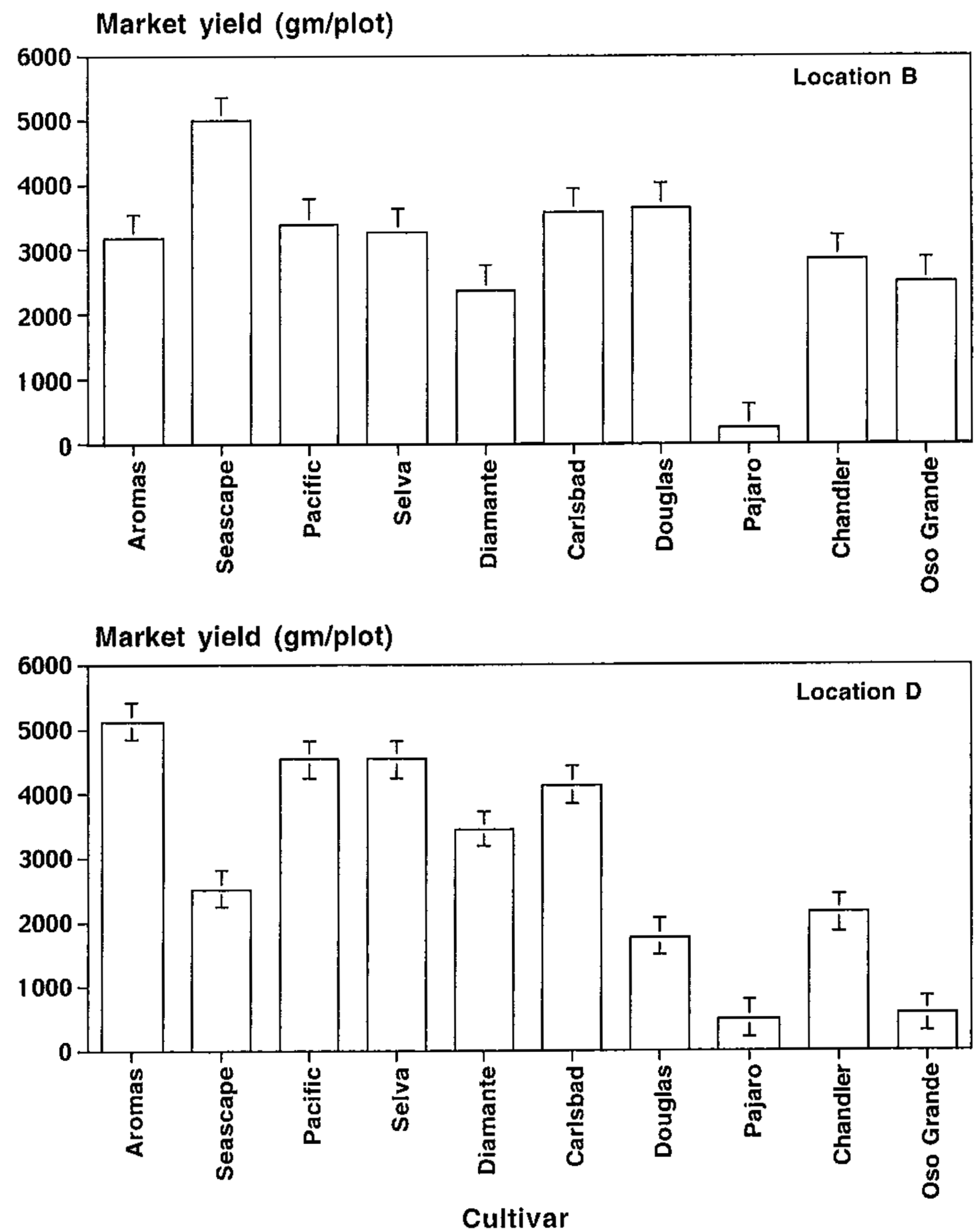

Figure 2. Cumulative market yield of commercially available cultivars grown under organic management in certified organic fields (2000-2001). Yield was measured on 20 plants per plot by weighing marketable fruit once (Locations A and B) or twice (Location D) weekly. Perpendicular bars represent the standard error for the experiments.

Table 3. Commercial mycorrhizal products used in these experiments.

Product	Manufacturer
Ascend PA	BioScientific, Inc.
BioVam	EcoLife, Corp.
Endomycorrhizal Inoculant	Bio/Organics, Inc.
EndoNet	Reforestation Technologies International
Vaminoc	Microbio, Ltd. Royston Herts, UK
Endos	AgBio, Inc.
Strawberry Saver	Plant Health Care, Inc.

Table 4. Mycorrhizal colonization of transplants from west coast nurseries.

	Mycorrhizal colonization (% root system colonized ± standard deviation)	
Cultivar	1999	2000
Aromas	1.7 ± 0.6 A[Y]	
Aromas (mcd)[Z]		29.9 ± 2.0 BC
Aromas (mca)		30.3 ± 2.7 BC
Aromas (sc)		33.1 ± 3.3 AB
Camerosa	0.0 ± 0.0 A	
Capitola	0.5 ± 0.5 A	
Carlsbad		22.3 ± 2.4 DEF
Chandler		26.1 ± 2.2 CD
Diamante	0.5 ± 0.9 A	
Diamante (sh)		24.4 ± 2.0 DE
Diamante (fr)		21.5 ± 2.9 DEF
Diamante (pgf)		37.1 ± 0.9 A
Douglas	0.2 ± 0.3 A	17.2 ± 2.7 F
Hecker	0.3 ± 0.3 A	
Oso Grande		25.9 ± 2.5 CDE
Pacific	0.7 ± 0.3 A	11.7 ± 6.0 G
Pajaro	1.3 ± 1.1 A	22.0 ± 2.8 DEF
Seascape	1.5 ± 1.5 A	20.9 ± 2.3 EF
Selva	0.0 ± 0.0 A	23.4 ± 2.5 DE
Sequoia	0.2 ± 0.3 A	

[Y]Means followed by the same letter are not significantly different according to Tukey's HSD at $P = 0.05$ for 1999 and P=0.01 for 2000.
[Z]Initials following Aromas and Diamante indicate the location of the nursery in which the plants were grown: mcd- McDoel; mca= McArthur; pgf= Pacific Gold Farms; sh=Shastina; fr= Fall River. Within each experiment, each cultivar came from a single location.

Table 5. Mycorrhizal colonization of strawberries (cv. Aromas) over time.

	Colonization of strawberry roots (% colonized)		
Sampling Time	Location 1	Location 3	Location 4
Transplants	33.1 C[Y]	33.1 C	29.9 B
January	37.9 B	35.7 C	NT[Z]
March	45.7 A	51.1 A	51.1 A
May	46.4 A	46.0 B	46.0 A

[Y]Numbers followed by the same letter are not significantly different according to Tukey's HSD (P=0.05). Data from each location was analyzed separately.
[Z]NT=not tested

Table 6. Effect of commercial inoculants on colonization of strawberry (cv. Aromas, March 2001).

	Colonization of strawberry roots (% colonized)		
Treatment	Location 1	Location 3	Location 4
1[X]	42.5 [Y]	47.1	44.7
2	45.5	46.7	46.5
3	42.9	42.1	43.7
4	43.3	44.1	44.3
5	44.1	41.8	44.9
6	43.4	45.6	45.4
7	40.5	42.5	45.4
8	43.7	NT[Z]	45.6

[X]Treatment 1 is the uninoculated control; Treatments 2-8 were commercially available inoculants listed in Table 4.
[Y]No significant differences were detected at the P=0.05 level between any treatment and any of the locations.
[Z]NT=not tested

Table 7. Yield of strawberries inoculated with commercially available mycorrhizal inoculants and grown in organic or conventional production fields.

	Market yield (K gm/plot ± standard error)					
	2000			2001		
Treatment	A	B	C	A	B	C
1[X]	6.1 ± 0.5	5.6 ± 0.4	18.7 ± 1.2	12.0 ± 0.9	8.0 ± 0.7	13.1 ±2.0
2	6.9 ±0.5	7.1* ± 0.4	19.1 ± 1.2	12.4 ± 0.9	5.8 ± 0.7	11.0 ± 2.0
3	5.8 ± 0.5	6.7 ± 0.4	19.0 ± 1.2	11.6 ± 0.9	6.6 ± 0.7	14.9 ± 2.0
4	6.0 ± 0.5	5.2* ± 0.4	19.3 ± 1.2	12.0 ± 0.9	5.9 ± 0.7	11.1 ± 2.0
5	6.4 ± 0.5	5.7 ± 0.4	18.4 ± 1.2	12.8 ± 0.9	6.8 ± 0.7	NT
6	6.4 ±0.5	6.2 ± 0.4	19.1 ± 1.2	11.8 ± 0.9	6.8 ± 0.7	13.3 ± 2.0
7	5.8 ± 0.5	5.7 ± 0.4	20.0 ± 1.2	12.7 ± 0.9	6.8 ± 0.7	11.5 ± 2.0
8	6.4 ± 0.5	6.2 ± 0.4	NT[Z]	12.4 ± 0.9	7.9 ± 0.7	11.6 ± 2.0

[X]Treatment 1 is the uninoculated control; Treatments 2-8 were commercially available inoculants listed in Table 4.
[Y]*Marked pairs are significantly different from each other but not from the control (P=0.03) according to Tukey-Kramer HSD.
[Z]NT=not tested

APPENDIX. TECHNICAL TRANSFER

1. Grower meetings and field days

June 8, 1999. "Update on Strawberry Varieties, Old & New; What works for Organic production." Hosted by CAFF and Presented by Carolee Bull. Growers helped us to decide what varieties should be used in the variety trials.

October 23, 1999. "Strawberry research and production" Presented by Carolee Bull during the Salinas to the Sea tour of agricultural projects for philanthropists.

December 14, 1999. Salinas, CA. Carolee Bull, Sean Swezey, and Steve Gliessman presented "Update on current strawberry research and Biological Agricultural Systems in Strawberries (BASIS)." Carolee Bull reported on the cultivar and inoculant trials funded by DPR.

April 2000. Organic production methods meeting. CAFF hosted a meeting to develop a template for organic production. Many of the participants in the DPR project attended and worked on the project. An organic consultant, an organic grower and two PCAs participated in an open discussion of pest and beneficial monitoring activities, action thresholds, and treatment methods or response. The goal is to produce in-house guidelines as a reference for future research and management activities for organic growers.

April 4, 2000 Field day. Carolee Bull talked about the DPR funded cultivar trials on organic managed land. Approximately 25 growers attended, Watsonville, CA.

June 27, 2000. UCCE Annual Strawberry Field day. Approximately 200 growers and agriculture professionals attended. Fundamentals of organic production and the DPR funded research projects were discussed. A poster of the DPR research was available for growers.

June 28, 2000. USDA/ARS Annual Field day. CAFF provided outreach by making calls to 50 growers and PCAs the day before the meeting. Approximately 100 growers and agriculture professionals attended. Fundamentals of organic production and the DPR funded research projects were discussed. A poster of the DPR research was available for growers. Sandra Fischbin of Speedling Corp. let me know that because of the DPR work we reported on at this meeting she has started a program to develop organic plug plants for strawberry growers. We will work with her in the future to help growers learn to use them.

March 22, 2001. Dr. Bull presented "Biologically based and organic strawberry production alternatives to methyl bromide." In Watsonville, CA. Twenty growers and agricultural professionals attended this meeting. She presented results from the previous year's work and explained the current year's work. Excellent grower suggestions on assumptions made when extrapolating from conventional production to organic production.

June, 2001. Dr. Bull presented the talk "Effect of cultivar and commercial mycorrhizal inoculants on organic strawberry production" in Watsonville, CA, to the California Strawberry Commission and associated growers. The meeting was attended by approximately 200 growers and agricultural professionals. At this meeting, growers had the opportunity to tour one of the demonstration plots. Additionally we provided a summary of the funded research to the California Strawberry Commission for handing out at all of their field days in Irvine, Oxnard, Santa Maria and Watsonville. Dr. Bull attended the Oxnard meeting.

July, 2001. Dr. Bull presented the talk "Role of microbial inoculants and cultivar selection on performance of organic strawberry production " to approximately 150 growers and agricultural professionals at the USDA/ARS field day, , Salinas, CA.

2. Information provided to agricultural professionals

September 2001. Dr. Bull provided information on the performance of strawberry cultivars in organic production systems to Maxwell Norton, University of California Cooperative Extension Merced County, CA,

Dr Bull provided detailed information about research on cultivars and/or microbial inoculants and organic or biologically based production of strawberries for the following scientists: 1) Dr. Pedro Buff, University of Wageningen, The Netherlands, 2000; 2) Dr. David Taylor, East Malling, UK, 2000.

3. Popular media stories about the research

The Foghorn July 1999 "Update on Strawberry Varieties Old and New, and What Works for Organic Production" Written by Foghorn staff June 8, 1999 (report on lunch time meeting).

Farmer to Farmer (formerly the Foghorn) May 2000. Write up on April 4 field day.

The Cultivar, newsletter of the UCSC Center for Agroecology & Sustainable Food (M. Brown) Articles include: Research updates (1999. 17:2, 7-8); Strawberry research project enters second season (2000. 18:1, 6-8); Research updates: Center takes part in variety trial (2000. 18:1,18); Second year of strawberry variety trial begins (2000. 18:2, 6-8); Study examines strawberry cultivars in organic systems (2001. 19:1). The Cultivar goes out to about 2,000 growers, academics, or extension agents in 65 countries, though most are in California.

The Cultivator Winter/Spring 2000. "Variety Trials Play key Role in Organic Farming" Discusses importance of DPR funded variety trials. Written by Dr. Carol Shennan Director of The Center for Agroecology and Sustainable Food Systems.

Food Chemical News (Janet Byron) "Organic, chemical and nonchemical methyl bromide alternatives explored for strawberries"(11/1999).

KSCO radio Good Morning Monterey (Rosemary Chalmerz) Organic strawberry production experiments and alternatives to methyl bromide. (6/2001).

Environmental News Network, (Chris Clarke) "Alternatives ripen for strawberry growers" ENN.com (1/2001).

ARS magazine (Marcia Wood) Cover story "Strawberry fields forever…without methyl bromide." This article has photographs and limited information from DPR funded research plots. This magazine is distributed nationally (1/ 2001).

4. Professional seminars and publications from the research

Bull, C. T., 1999. Factors Influencing integrated methods for control of soilborne diseases of strawberry. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, CA. (abs).

Bull, C. T., Stryker, J., Koike, S. T., and Shennan, C. 2000. Use of mycorrhizal inoculants in organic production of strawberries. p. 272. Proceedings of the 13th IFOAM Scientific Conference Basel, Switzerland, 2000.

Bull, C. T., 2000. Organic Research in the USDA/ARS. Poster presented at the USDA/ARS National Program Meeting (600 farmers and scientists) San Diego, CA, October28-November 2, 2000.

Bull, C. T., 2000. Research Models for Maximizing the Impact of Organic Research Conducted with Limited Resources. IFOAM 2000. Basel Switzerland. August 2000.

Bull, C. T., 2000. Participatory Research for the Dynamic California Strawberry Industry. Proceedings of the Western Region SARE conference. Portland, OR, March 2000.

F. N. Martin, and C. T. Bull. 2000. Biological approaches for control of some root pathogens of strawberry. Phytopathology 90:S102. Dr Bull and a collaborator were invited to present this paper at a symposium "Methyl Bromide Alternatives: Progress Toward Meeting Deadlines" which included information about the funded research. This paper was presented at the national meeting of the American Phytopathological Society, New Orleans, LA, 2000. Paper will be published from this symposium in Phytopathology in 2002.

Bull, C. T., Koike, S. T., and Shennan, C. 2001. Performance of commercially available strawberry cultivars in organic production fields. Will be published by and presented to the Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions in San Diego, CA, November 5-9, 2001.

Dr. Bull is invited to present the seminar "Research on organic strawberry production" to UC-SAREP. She discussed the funded research and pinpointed additional areas of research needed. November 1, 2001, Davis, CA.

Bull, C. T. Nurseries, Planting Material, and Varieties. This chapter is in preparation for the UC-SAREP sponsored DANR publication *Organic Strawberry Production Manual.* The data from the funded research will be included in the chapter (in preparation).